Sounding Rocket Program
Update to the Heliophysics Subcommittee

July 2, 2012

HELIOPHYSICS

C. Yuhas

Sounding Rocket Program

- Heliophysics FY12 Suborbital Missions Update
- Program Implementation Status
  - 2012 launch schedule
  - Range Updates
  - Motor Status
- Peregrine Motor Development

Heliophysics Suborbital Missions Update

- Heliophysics Rockets Launched in FY2012
  - CHAMPS (Charge and Mass of Meteoritic Smoke Particles); Oct 12 & 13, Andoya.
  - MICA (Magnetosphere-Ionosphere Coupling in the Alfven resonator), Feb 19, Poker Flat
  - ATREX (Anomalous Transport Experiment), March 27, Wallops
  - SDO/EVE Calibration, June 23, WSMR
- Upcoming Rocket Missions
  - SUMI (Solar Ultraviolet Magnetograph Investigation), July 5, WSMR
  - Hi-C (High Resolution Coronal Imager), July 11, WSMR
  - DFS (Degradation Free Spectrometers for Solar Physics), July 24, WSMR
  - EVEX (Equatorial Vortex Experiment), September, Kwajalein
  - EUNIS, FOXSI, VERIS, RAISE, Aug-Oct, WMSR
- Other Suborbital Missions
  - GRIPS (Gamma Ray Imager/Polarimeter for Solar Physics); delayed by PI, working with Balloon Program for next launch opportunity.
  - BARREL (Balloon Array for RBSP Relativistic Electron Losses); on track for Antarctic deployment this fall.

ATREX Mission, March 27, 2012: 5 rockets in 5 minutes

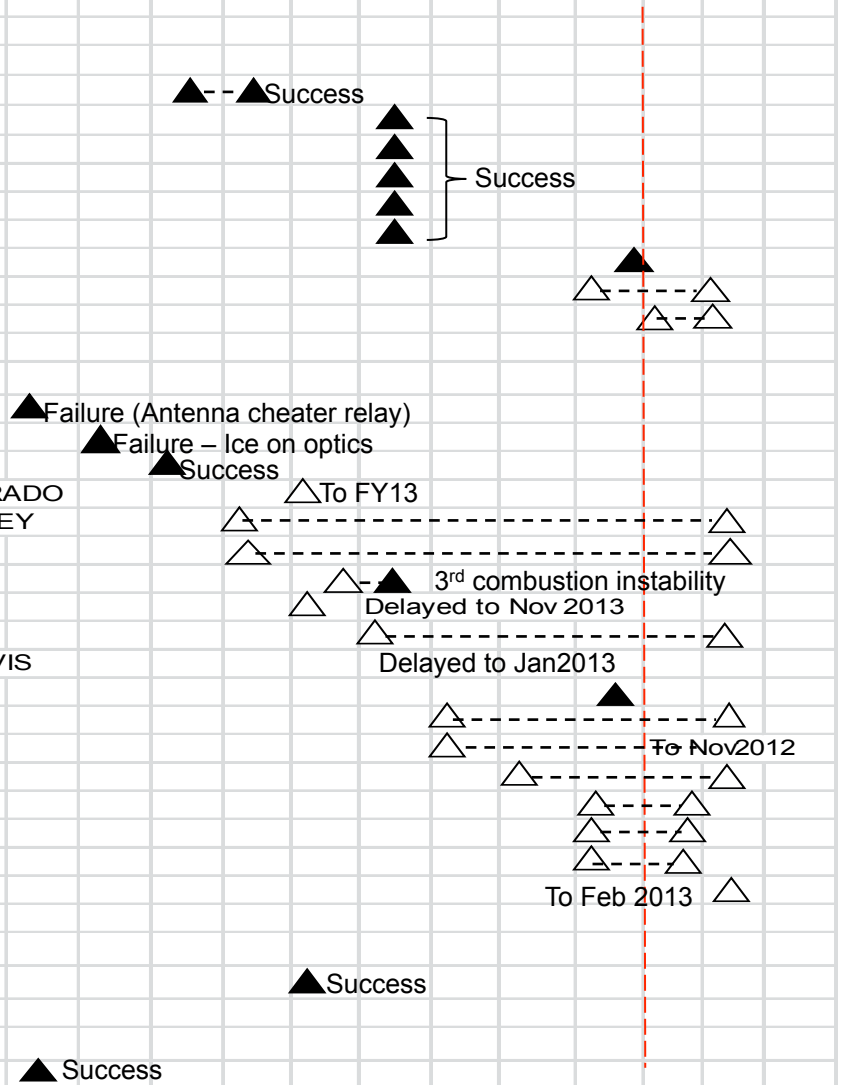
Time Lapsed Launch Sequence

Multiple Downrange Clouds

FY12 Sounding Rocket Schedule

Combined flights supporting a single scientific study

#	Vehicle Type		FY 2012 Experimenter
			WALLOPS ISLAND
1	Test Vehicle	12.074 GT	Terrier-MalemuteHALL/NASA-WFF
2	Terrier Malemute	46.002 UE	ATREX-LARSEN/CLEMSON UNIVERSITY
3	Terrier Oriole	45.004 UE	ATREX-LARSEN/CLEMSON UNIVERSITY
4	Terrier Orion	41.097 UE	ATREX-LARSEN/CLEMSON UNIVERSITY
5	Terrier Orion	41.098 UE	ATREX-LARSEN/CLEMSON UNIVERSITY
6	Terrier Orion	46.003 UE	ATREX-LARSEN/CLEMSON UNIVERSITY
8	Terrier Orion	41.101 UO	RockOn-KOEHLER/UNIV OF COLORADO
9	Test Vehicle	12.075 GT	Talos-Terrier-Oriole/BRODELL/NASA-WFF
10	Terrier Malemute	46.004 GO	ROSANOVA/NASA-WFF
			WSMR
11	Black Brant IX	36.225 UG	PICTURE-CHAKRABARTI/BOSTON UNIV
12	Black Brant IX	36.264 UH	XQC-MCCAMMON/UNIV. OF WISCONSIN
13	Black Brant IX	36.274 UH	EXOS-CASH/UNIV. OF COLORADO
14	Black Brant IX	36.271 UG	SLICE-BEASLEY/UNIVERSITY OF COLORADO
15	Black Brant IX	36.255 US	FOXSI-KRUCKER/UNIV. OF CA @ BERKLEY
16	Black Brant IX	36.268 UG	FORTIS-MCCANDLISS/JHU
17	Black Brant IX	36.277 UG	CIBER-BOCK/CAL TECH
18	Black Brant IX	36.261 UG	VeSpR-CLARKE/BOSTON UNIVERSITY
19	Black Brant IX	36.260 UG	IMAGER-COOK/BOSTON UNIVERSITY
20	Black Brant IX	36.235 US	HYPE-HARRIS/UNIV OF CALIFORNIA,DAVIS
20A	Black Brant IX	36.286 UE	EVE-Woods/UNIV OF COLORADO
22	Black Brant IX	36.269 GS	EUNIS-RABIN/NASA-GSFC
21	Black Brant IX	36.253 US	RAISE-HASSLER/SWRI
22	Black Brant IX	36.239 DS	VERIS-KORENDYKE/NRL
23	Black Brant IX	36.272 NS	SUMI-CIRTAIN/MSFC
24	Black Brant IX	36.284 NS	Hi-C-CIRTAIN/MSFC
25	Black Brant IX	36.263 US	DFS-JUDGE/USC
26	Black Brant IX	36.262 UG	ACCESS-KAISER/JHU
			PFRR
27	Black Brant IX	36.273 UE	MICA-POWELL/CORNELL UNIVERSITY
			NORWAY
28	Terrier Orion	41.093 UE	CHAMPS-Robertson/University of Colorado
29	Terrier Orion	41.094 UE	CHAMPS-Robertson/University of Colorado

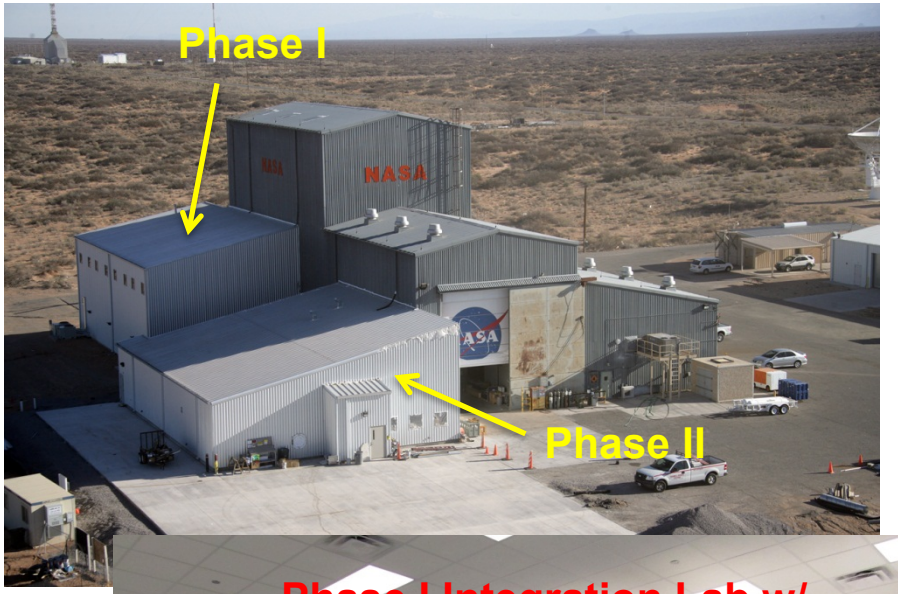


FY12 Sounding Rocket Schedule

#	Vehicle Type		FY 2011 Experimenter	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
			KWAJALEIN												
30	Terrier Malemute	46.001 UE	EVEX-KUDEKI/UNIVERSITY OF ILLINOIS												△
31	Terrier Oriole	45.005 UE	EVEX-KUDEKI/UNIVERSITY OF ILLINOIS												△
32	Terrier Orion	41.100 DR	CATON/USAF												△
33	Terrier Orion	41.102 DR	CATON/USAF												△
			REIMBURSABLE MISSIONS												
35	Black Brant XI	41.102 DR	IRVEIII-CHEATWOOD/NASA-LARC							△			△		

Sounding Rockets Range Updates

- White Sands Missile Range, New Mexico
  - LC-35/LC-36 consolidation to be complete this fall
  - New integration lab (Phase I) is up and running – two solar missions presently in integration
    - Cirtain 36.272 and 36.284
  - PI's are very pleased with new facility – "vast improvement"
  - Phase II construction 95% complete
    - NASA walk through conducted last week
  - Phase III (final) is 50% complete
    - TM ground station consolidation



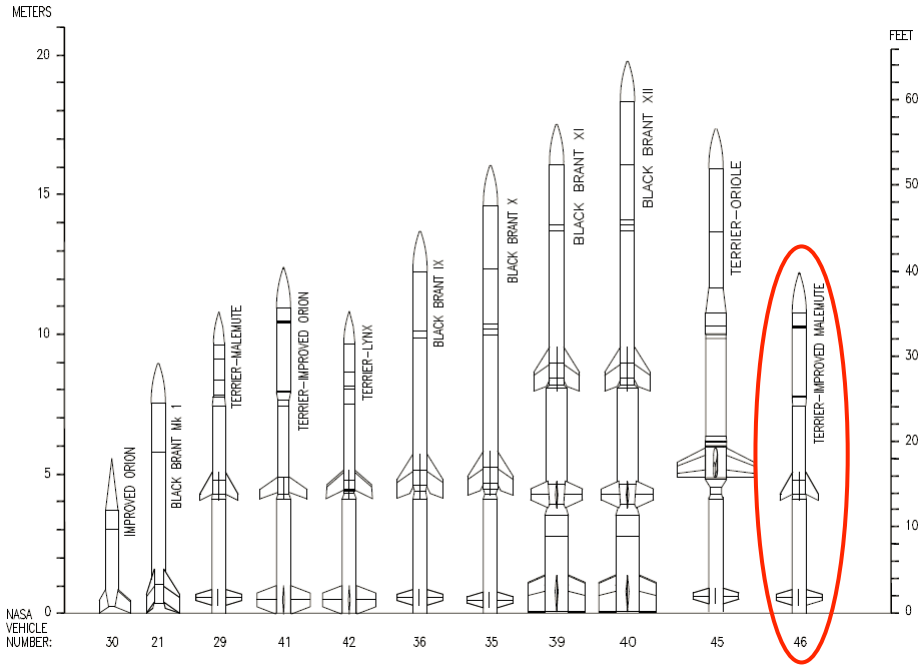
Sounding Rockets Range Updates

- Poker Flats Research Range, Alaska
  - Environmental Impact Statement on track for public release this fall
    - Expect to be at HQ for review mid-July
    - Public meetings will be held in Fairbanks and Anchorage this fall
    - Great cooperation with USFWS, BLM
  - Range ready to support 40.027 Rowland this winter (February)
    - Return of Black Brant XII to flight status
- Reagan Test Site, Kwajalein Atoll
  - Team there now installing launcher for campaign this September
  - Optimistic we can make this a routine “equatorial” launch site from both technical and cost perspectives
- Woomera Test Range, South Australia
  - In discussions via HQ with Australian officials about making NASA a “non-commercial” launch operator
  - Plans for a 2014 or 2015 campaign in early stages but appear feasible assuming gov’t to gov’t agreements are in place

Rocket Motor Status

Rocket Motor Status

- Surplus Motors
  - Added Terrier-Improved Malemute to vehicle stable. Test Flight Jan 2012, first use in ATREX, March 2012.
- Brant Motors
  - In flight-status, but technical issues continue.
- Oriole Motors
  - 6 Oriole motors have been added to inventory as Brant alternative.
  - Length-to-Diameter ratio results in lower vehicle stability than Brant; reduces the spectrum of payload configurations that can be accommodated.
  - Composite casing is less robust and more vulnerable to logistic and operating conditions.
  - First use in ATREX mission demonstrated residual thrust; potential for motor to overtake payload in some configurations.
  - Test flight of Talos-Terrier-Oriole this summer.



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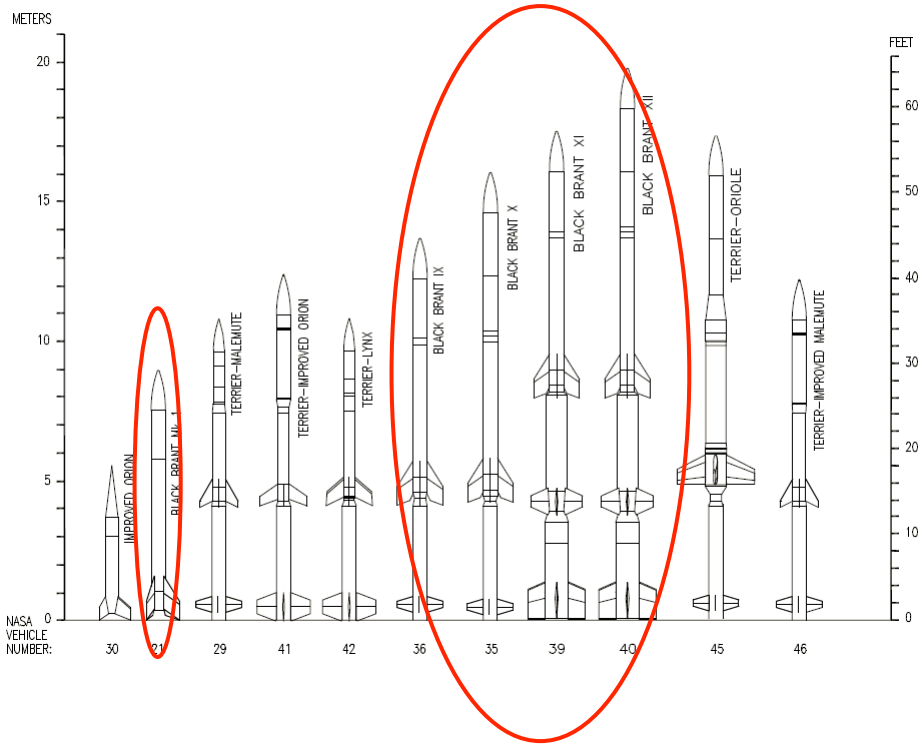

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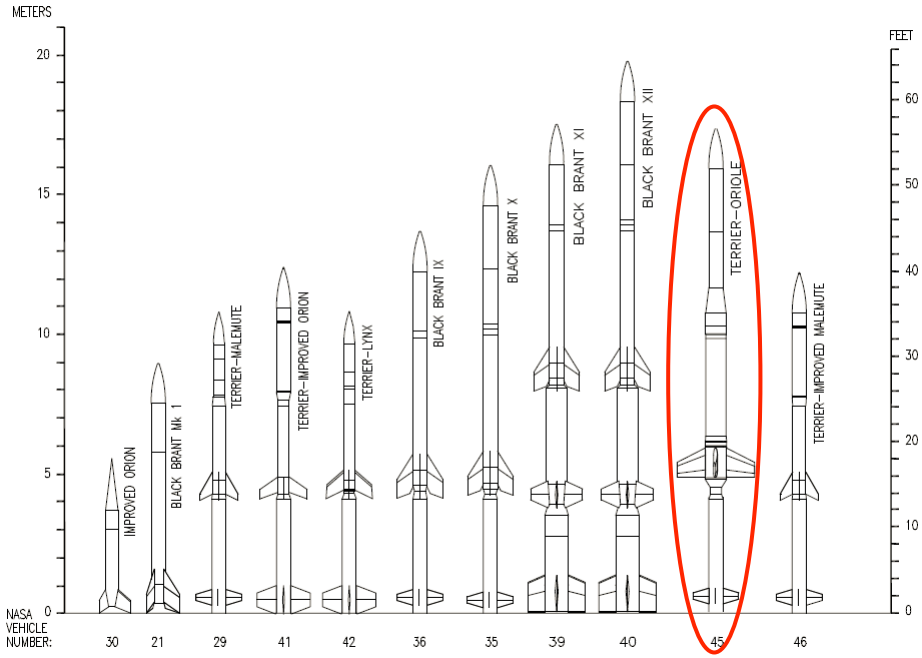


Rocket Motor Status

- **Black Brant Motors**
  - Technical Issues with Mark 1 motor since introduction in 2005: igniter, casing test failures (resolved); combustion instability (mitigate & watch), unusual dynamics (unresolved).
  - Combustion Instability:
    - 3 of the last 30 BB launches have experienced combustion instability, causing 2 mission failures due to excessive vibration. Biggest concern is safety, since high vibrations could damage or disable the FTS (WSMR).
    - Mitigation: throat enlargement, US ammonium perchlorate, flight rules allows FTS initiation at first sign of instability.
  - Unusual Dynamics:
    - Excessive nozzle erosion, regressive chamber pressure profiles, flight dynamics that can introduce unsafe flight trajectories to upper stages.
    - Bristol investigated alternative propellant mix methods, nozzle & exit cone designs, alternative suppliers.
    - Terrier-Brant (BBIX) authorized to fly based on multiple safety analyses; moratorium in place on other Brant configurations.

Black Brant XII:
Talos-Taurus-Brant-Nihka

Rocket Motor Status

Recent Performance (June 23 flight):

The first flight of the BB Mk2 Version I motor (hybrid 4140/4335 steel case with US manufactured WECCO ammonium perchlorate propellant) was conducted with the 36.286/Woods mission from WSMR on June 23

- No signs of anomalous flight behavior
- Accelerometer and roll rate data looked nominal with no signs of combustion instability
- Motor hardware was recovered and aft end insulation was in better condition than other MK1 motors (excepting the Combustion Instability occurrences)
- Aft carbon phenolic exhibited reduced throat erosion that was more uniformly distributed around the perimeter with approximately 1/2” material remaining in the area of maximum erosion (good margin)
- Results indicate that the US AP is burning more efficiently causing less erosion with performance characteristics more similar to the old Brant design

Black Brant XII:
Talos-Taurus-Brant-Nihka

Rocket Motor Status

- **Black Brant Motors**
  - Inventory Status:
    - Bristol Aerospace is currently maintaining schedule for delivery of Black Brant rocket motors.
    - We now have 14 motors total in stock at various locations and conditions, a record number for recent history!
      - Three motors cannot be flown at WSMR due to high-end burn rates
      - Various levels of work needs to be done on some other motors (x-ray, throat boring, etc.)
    - 14 missions are currently on schedule for remainder of CY; Dynamics in launch dates, uncertainties in access to x-ray facilities, and final motor delivery schedules make it difficult to know if missions will be impacted

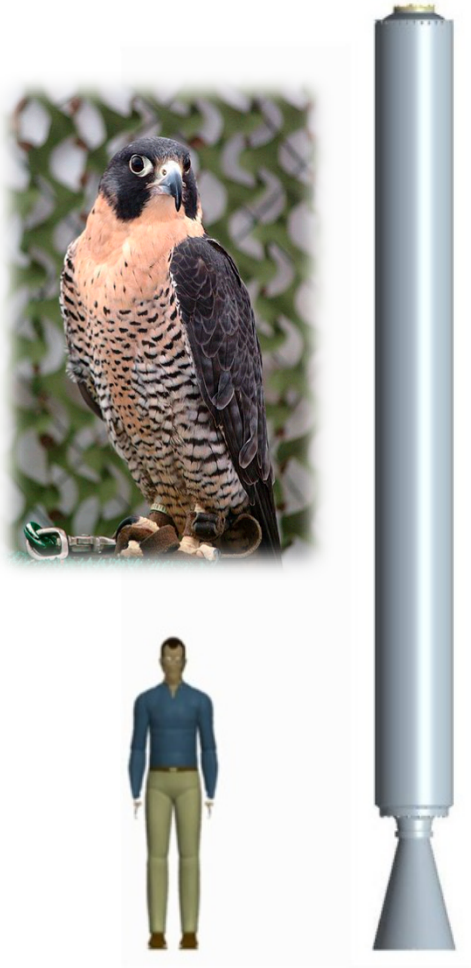
- **Flight Termination Systems**
  - New FTS delivered and in use at WSMR.
  - NICAD battery supplier 'vanishing vendor' is a risk item; alternate batteries have been ordered from multiple new vendors and are being qualified for use in FTS.

Black Brant XII:
Talos-Taurus-Brant-Nihka

Peregrine Motor Development

- SMD has initiated a development project of a purpose-built sounding rocket sustainer motor using an approach where the government collaborates with industry to generate a build-to-print system that can be produced by multiple vendors.
- Objective of the Peregrine Motor Project is to provide a reliable, affordable alternative to the Brant and Oriole motors.
- SMD has partnered with NASA's Office of Chief Engineer and the Office of the Chief Technologist, because of compatible objectives: workforce development (OCE) and flights of opportunity for technology demonstration payloads (OCT).
- 18-month development schedule for detailed design, manufacture, 1 static firing test, and 3 test flights.

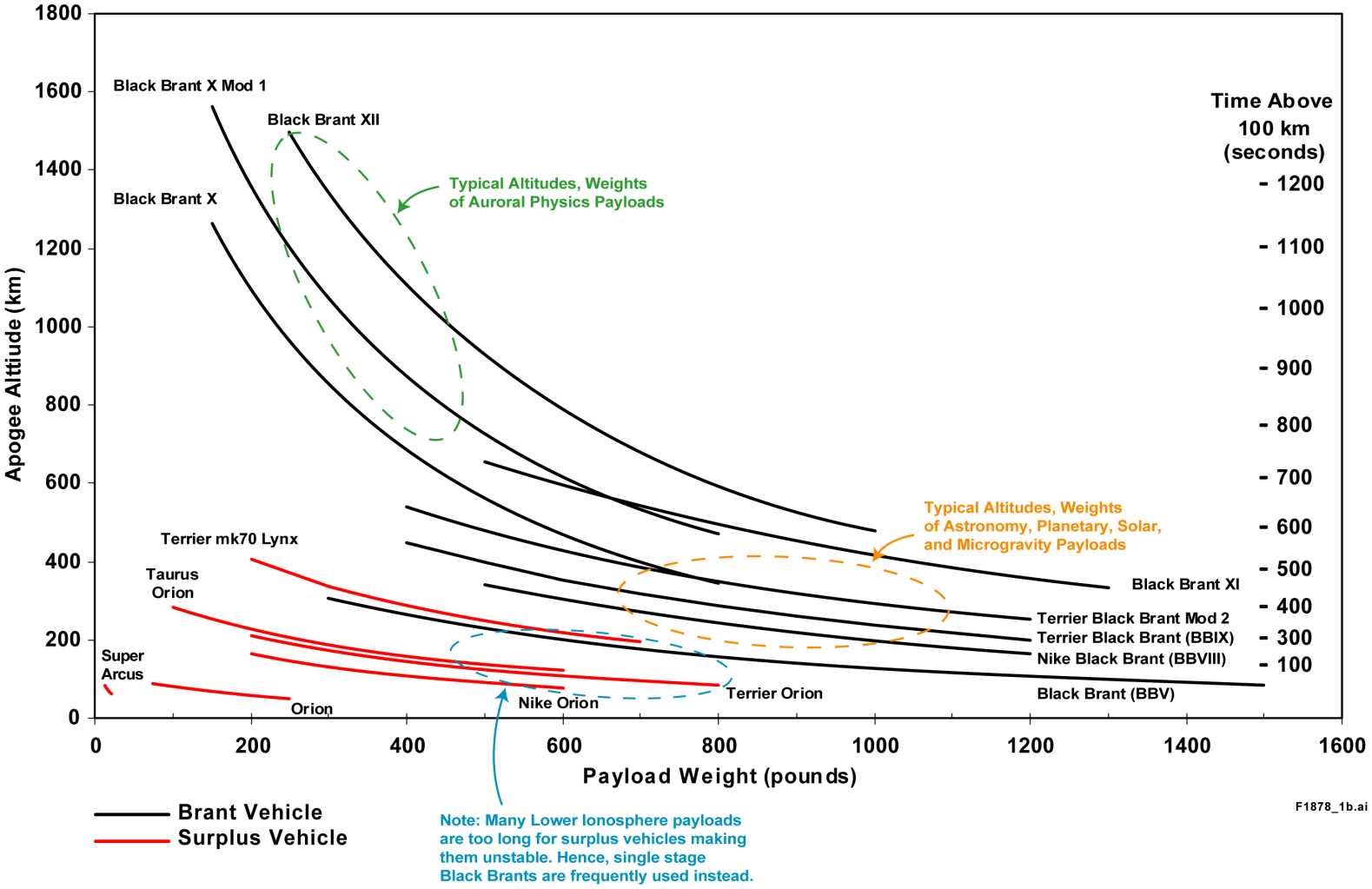
- Status: Preliminary design reviews completed March 2012; proposals for casing and casting of motors are in evaluation. First test flight in summer 2013.



Backup

Suborbital Observing Capabilities: Sounding Rockets

NASA Sounding Rocket Vehicle Performance

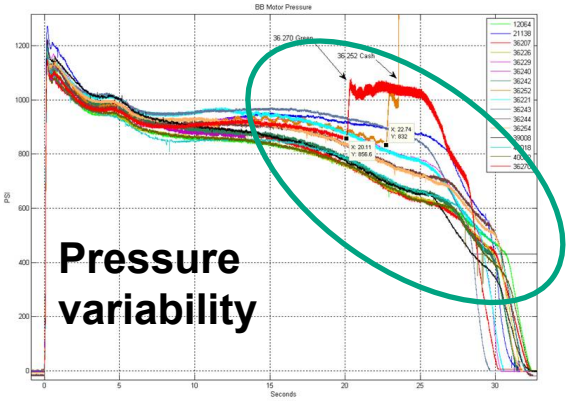


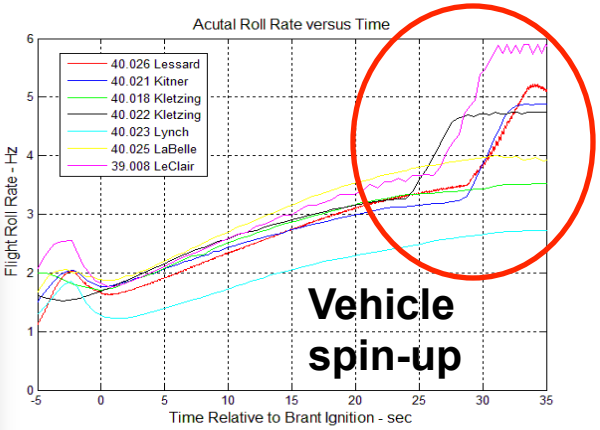
Summary of Need for "Purpose-build" Sounding Rocket Motor

- The sounding rocket program attempts to use surplus military rocket motors as much as possible, but must rely on commercial motors to fulfill some critical applications
  - Limited budget means that low-cost assets are critical to the continued success of the program
- Industry dynamics have lead to a "single source vendor" situation that has adversely affected the program
  - Reduced corporate responsiveness exists under the current situation
  - Limited production capacity has made it impossible to rebuild inventory that enables program agility (thus a hallmark of the program has been lost)
- Existing US solid propellant rocket motors are not ideal for NASA Sounding Rocket Applications
  - Higher cost associated with the existing options is inconsistent with the low-cost nature of the NASA sounding rocket program
  - Adopting a radically different propulsion system or vehicle philosophy could require wholesale redevelopment of significant program assets
- Emerging commercial reusable vehicle companies can not currently satisfy the extensive requirements of the scientific community needing access to sub-orbital space flight
- A NASA-owned, non-proprietary design will allow the SRPO to efficiently and cost effectively incorporate design changes and enhancements as required by the program

Ongoing Brant Issues

- Igniter design deficiencies
- Black Brant inconsistent performance and thrust profile variability
- Combustion instabilities
- Excessive throat erosion and associated dynamics
- Motor casing test failures
- Suspect Ammonium Perchlorate
- Redesignated as 1.2 explosive
- Delivery delays
- Single source vendor
- Foreign vendor
- Reduced Bristol expertise

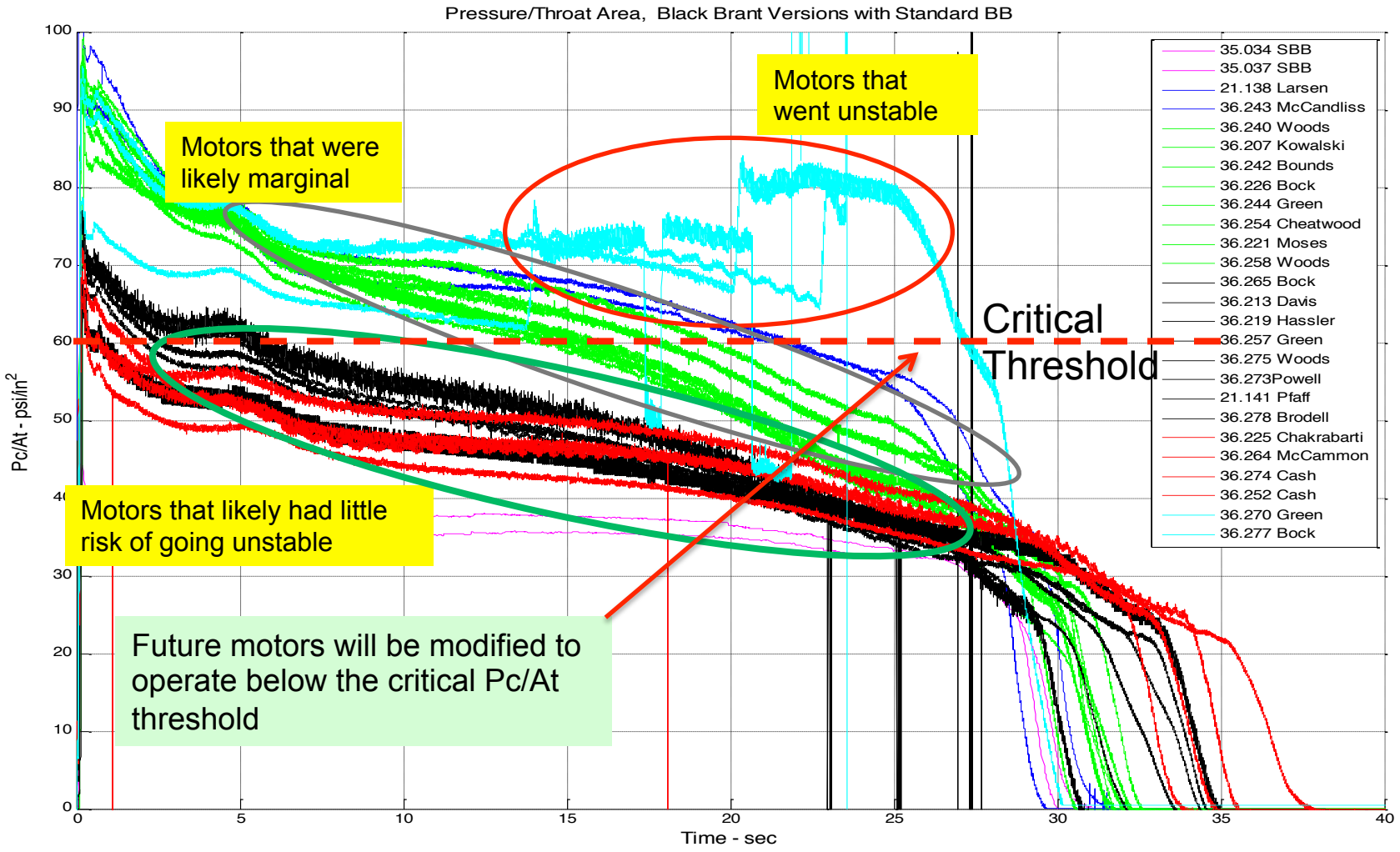




BBIX Throat erosion

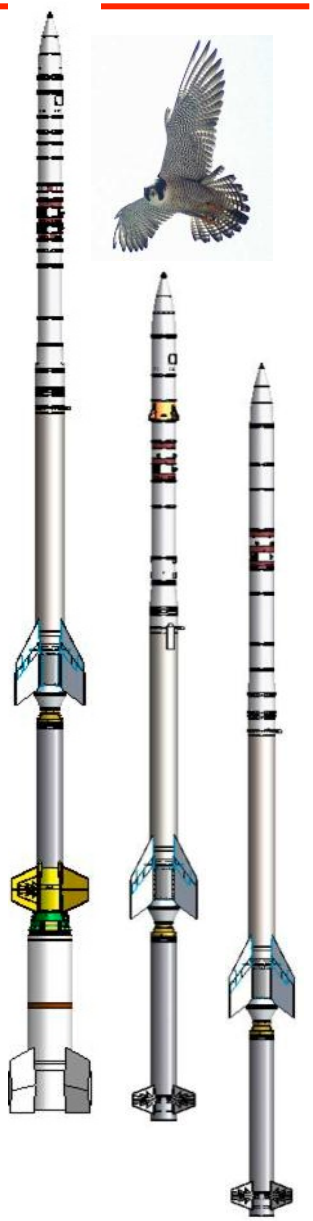
Some of these issues have been rectified and some are still on-going

Black Brant Rocket Motors



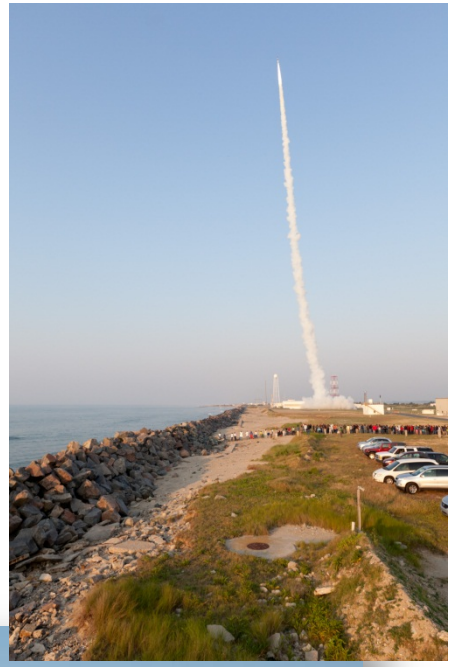
Peregrine Status

- Request for Proposals for demonstration propulsion unit fabrication (Case, Cast, and Combined) went out to bidders on 5/1/12
- Proposals have been received and are being evaluated
  - Questions/clarification request(s) provided to proposers by 6/7/12
  - Selection and contract award planned to occur by end of June
    - Proposal cost and schedule input will firm project direction
- Engineering Project Review Board (EPDR) meeting was conducted on 5/18/12 and top risks identified
- Requirements Definition Meeting (RDM) for the three test flight payloads was conducted on 5/18/12
- Additional near-term activities
  - Complete five gallon mix propellant characterization
    - Mechanical properties at hot/cold temperatures
    - Burn rate characteristics at hot/cold temperatures
  - Static test 10 lb thrust test motors (4)
  - Prototype igniter case fabrication to be completed b y NSROC in June
  - Complete design/analysis on tailcan and fins
  - Develop environments prediction(s) to support FTS approach
  - Complete Design and Analysis Cycle (DAC)-1 final report



Outreach:

1. **Wallops Rocket Academy for Teachers and Students (WRATS)**
   a. Lessons and activities being refined
   b. Workshop starts on June 18



2. **RockOn Workshop and University Experiment Mission**
   a. WFF payload system integration and test underway
   b. Workshop starts June 17
   c. Launch set for ~6AM on June 21

Sounding Rockets: Significant Progress

Magnetosphere-Ionosphere Coupling in the Alfven resonator (MICA), PI: Powell/Cornell, Poker Flat

- Launch window opened Feb. 13 with launch occurring on Feb. 19
- Mother / Daughter payload configuration measured electric fields generated by the aurora and electrons and ions interacting with the Earth's magnetic field
- Launch vehicle spin rate was lower than planned
  - This contributed to increased coning
  - One set of booms did not fully deploy as planned but still collected good science data
  - Both items are under investigation
- Principal Investigator has stated the mission achieved the Comprehensive Success Criteria

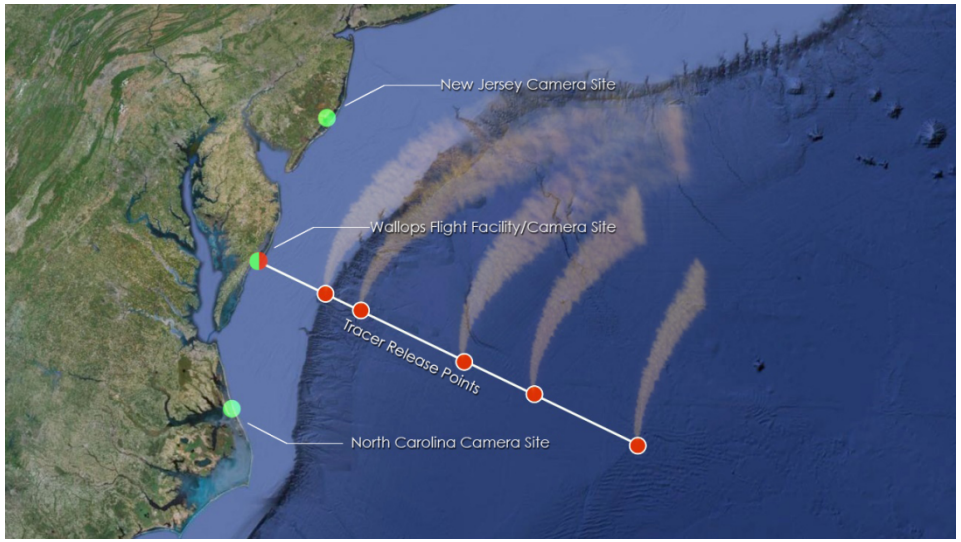
MICA launch from Poker Flat, Feb 19)

- **Cosmic Infrared Background Experiment (CIBER)** from WSMR, Mar 21(PI: Bock/JPL); re-scheduled from Feb 24 to re-verify fin settings.
- **Focusing Optics X-ray Solar Imager (FOXSI)** from WSMR, March (PI: Krucker/Berkeley); indefinitely delayed following damage to detectors during I&T.
- **Venus Spectral Rocket (VeSpR)** from WSMR, (PI: Clarke/Boston U); PI missed March launch slot; re-assigned FORTIS slot in April.
- **Far-ultraviolet Off Rowland-circle Telescope for Imaging and Spectroscopy (FORTIS),** PI: McCandliss/JHU; PI unable to make April slot; SRPO negotiating with WSMR for new slot.

Sounding Rockets: Significant Progress

Anomalous **Tr**ansport **EX**periment (ATREX) **Launch Operations:**

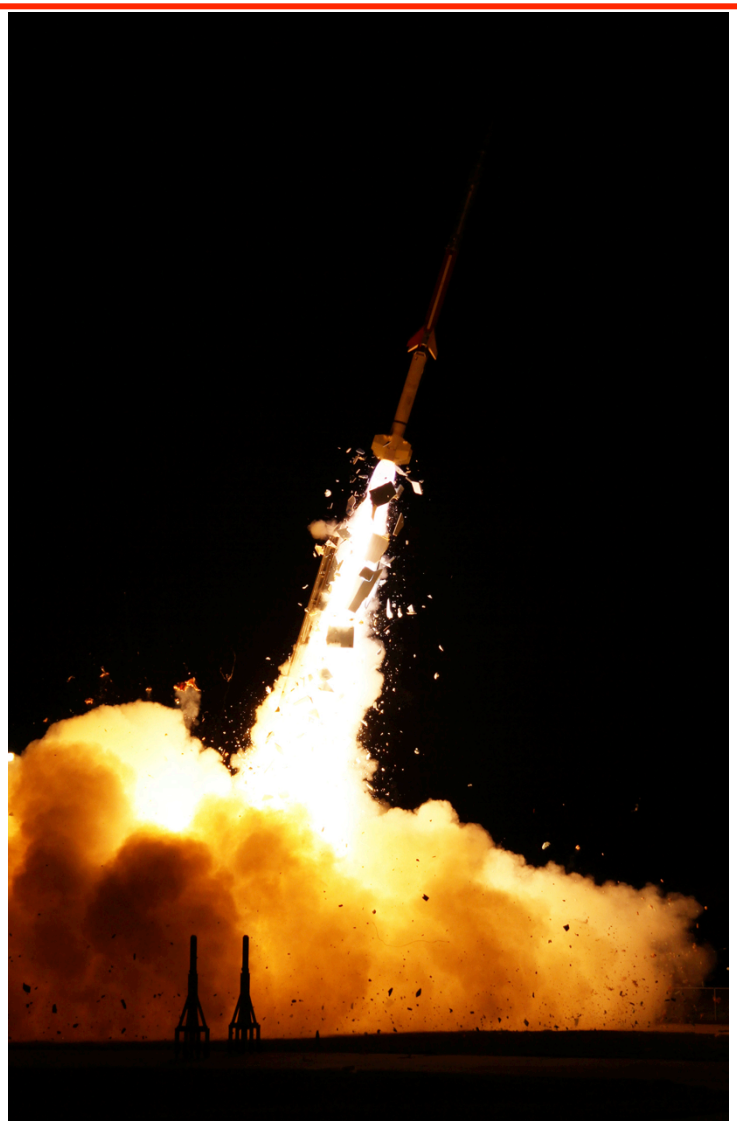
- PI: Larsen/Clemson University
- Science objective is to study ultra-high-altitude winds in the thermosphere and their connection to the electrical current patterns that surround Earth.
- Launch window is March 14 through April 4, 11pm – 6am.
- Five rockets launched during a five minute window. First science use of Terrier-Oriole and Terrier-Improved Malemute vehicles.
- All payloads have chemical releases and some have instrumentation
- Accurate collinear and vertical placement of all chemical releases with simultaneous visibility from three camera viewing locations is required (New Jersey, Virginia, & North Carolina)
- Launch conditions require clear, moonless skies from all 3 camera sites.



Launch Profile Overview


Launch Rehearsal March 15

Boxed Rockets



Out of the Box!!!

Rocket Trails in the Milky Way, Photo courtesy of J. Lodigruss